

UNIVERSITY OF KANSAS SCIENCE BULLETIN

Vol. XXVII, Pt. 1

DECEMBER 15, 1941

No. 6

Paleoecology and Correlation of the Rexroad Fauna from the Upper Pliocene of Southwestern Kansas, as Indicated by the Mammals

BY

CLAUDE W. HIBBARD

THE UNIVERSITY OF KANSAS SCIENCE BULLETIN

Vol. XXVII, Pt. 1, No. 6, Nov. 1, 1941



THE UNIVERSITY OF KANSAS SCIENCE BULLETIN

VOL. XXVII]

NOVEMBER 1, 1941

[No. 6

Paleoecology and Correlation of the Rexroad Fauna from the Upper Pliocene of Southwestern Kansas, as Indicated by the Mammals¹

CLAUDE W. HIBBARD,

Museum of Vertebrate Paleontology, University of Kansas

ABSTRACT: Field technique used for the recovery of small fossils by the Kansas University Museum of Vertebrate Paleontology is described. A measured section is given of one of the best-known exposures of the Upper Pliocene in western Kansas. The age of the Rexroad fauna is discussed, and a comparison is made with other known Upper Pliocene faunas of North America. A list of the mollusks found associated with the vertebrate fauna is given as identified by F. C. Baker, also a list of the Rexroad mammals, which comprises 8 orders, 37 genera and 32 identified species. The true Rexroad fauna shows relationships with forms now found in southwestern United States, Mexico and Central America rather than with Recent forms now found in southwestern Kansas. A discussion is given on the paleoecology of that time. The fauna indicates that meadow flats and timbered areas existed at least along portions of the Upper Pliocene stream valley, and that the climatic conditions then were not drier nor colder than at present. Moreover, there is some indication that climate in the Upper Pliocene was more equable than at present, without extremely cold winters or severely hot summers, and that there was a somewhat greater degree of humidity.

INTRODUCTION

THE Tertiary faunas of the Great Plains are inadequately known, and the smaller vertebrates especially have many times been overlooked. The reconstruction of the past mammalian life has until recently been based almost entirely on the larger and more conspicuous forms. Only occasionally have the remains of the smaller mammals been taken in association with the larger species. In fact, it was believed for years that the remains of the smaller vertebrates were mostly missing from the deposits. The demand for spectacular

1. A condensation of a dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the University of Michigan.

exhibits has led each field party to search for larger and better specimens, constantly overlooking, without a doubt, deposits containing small vertebrates. The practice of excavating with plow and scraper, followed by pick and shovel, to remove the greater part of the matrix around the larger bones probably has destroyed more vertebrate remains than have ever been recovered. My experience in collecting fossils has convinced me that almost any deposit that yields the bones of large mammals contains also the bones of the smaller forms. It seemed evident that a careful search of the deposits would yield a nearly complete fauna, adding much to the knowledge of its distribution through time and space, and its phylogeny, as well as helping to interpret the environmental conditions under which many of the forms lived.

The discovery of the Upper Pliocene deposits in southwestern Kansas led to intensified work in that area because the fauna was new and unknown for that part of the High Plains. Every effort is being made to recover as complete a fauna as possible. The fauna here described is noteworthy among Upper Pliocene faunas since it is the largest known in North America. The investigation of this fauna has involved the study of other known Upper Pliocene faunas and deposits, and careful comparisons have been made with them as well as with Pleistocene and Recent forms.

The small mammals, as a rule, furnish more knowledge of the past environment at the time when they lived than do the larger forms, since the former are generally confined to more specific ecological niches than the latter. The large number of small forms recovered in this area has made possible the reconstruction of past ecological conditions in a manner hitherto impossible because of insufficient material.

The attempted reconstruction here of the ecological conditions prevailing in southwestern Kansas in the Upper Pliocene has been based primarily on the adaptive characters exhibited by the animals and on the geological evidence shown by stratigraphic position and nature of the deposits. This reconstruction has been greatly facilitated by the deductions made possible by having this large fauna of small mammals available for study and by the comparison with the ecology of the present mammalian fauna.

ACKNOWLEDGMENTS

I am greatly indebted to Dr. Lee R. Dice, Dr. E. C. Case, Dr. W. H. Burt, and Dr. Carl L. Hubbs of the University of Michigan, and Dr. H. H. Lane of the University of Kansas, for advice and criticism during the preparation of this paper; and to Dr. John C. Frye of the United States Geological Survey and Dr. H. T. U. Smith of the University of Kansas, for their advice, which they have freely given me concerning the geology of Meade county and the surrounding area. The drawing was made by Miss Frances Watson.

FIELD OPERATIONS

While working in Meade county the past five summers (1936-'40), a number of exposures have been located that have yielded fossil vertebrates. These exposures have been numbered in the order in which they were located. The exact locations are not here published, but will appear after our work has been completed. Only three Upper Pliocene exposures have been found which contain fossils. These exposures are known as Localities Nos. 1, 2 and 3, and will be referred to as such in this paper. These three localities are situated in a nearly due north-and-south direction from one another within a distance of three-fourths of a mile along side branches of a tributary stream of Crooked creek, each locality being separated from the others by a narrow divide covered with Pleistocene and Recent deposits.

The fossil remains in the Upper Pliocene deposit of Meade county, Kansas, were first found by CCC workmen who removed them for souvenirs. Dr. M. K. Elias, in the spring of 1936, visited one of the quarries in Meade county, Kansas, where consolidated sand was being removed to be used as riprap on a state lake project. While there, he inquired about the presence of fossil bones and was presented with isolated teeth which had been removed from deposits below the stone quarries. Upon his return to the University of Kansas, the specimens were given to the Museum of Vertebrate Paleontology and the deposit was reported with the information given that considerable material had been removed, chiefly isolated horse teeth, and a number of mastodon teeth.

Upon our arrival in Meade county in the summer of 1936, it was found that the entire deposit so far as was known at that time had been worked by men from a CCC camp. The men had uncovered parts of five mastodon skeletons, including a number of tusks, lower jaws, and parts of skulls, at the locality now known as No. 3. The

exposed material was then swept away by a cloudburst, and the only trace of fossils left was a few bits of ivory scattered along the stream bed. It was reported that one small deposit of sand, now known as Locality No. 2, had yielded many teeth and small lower jaws, but these had been scattered and only a few isolated horse teeth were located. The teeth had been divided among the workers, who would not part with them. This locality was visited and found to have been exhausted, but the careful sifting of the CCC dump at this locality, and the sifting of another dump one-half mile north, known as Locality No. 1, yielded the fauna described by Hibbard (1938) as the "Rexroad fauna," after the name of the ranch on which it was collected. The siftings yielded a greater small vertebrate fauna from these two localities than had previously been recovered by the use of the team and scraper during a number of years' collecting in Kansas. Encouraged by this, our work has since been chiefly confined to the recovery of the small vertebrate fauna from the Upper Pliocene deposit in southwestern Kansas.

The CCC camp was abandoned by the spring of 1937, and thereafter we could proceed undisturbed with our investigations. The summer of 1937 was spent looking for favorable outcrops, and the removal of small fossils. One week was spent reworking Localities Nos. 1 and 2. Work was then started on Locality No. 3, which is one-fourth mile south of Locality No. 2. Here a few small bones were exposed in some lenses of fine sand within sandy silt. The sand was removed with awls. The bones when exposed were very fragile because of the moisture content. As soon as a small shovel full of sand was removed, it was placed on a towel to dry. When the sand was thoroughly dry we began the slow process of looking over the material for fossils and their removal from the sand with a pair of tweezers. Then the sand was carefully put through a sieve. The contents left in the sieve were again looked over, while that which went through the sieve was carefully examined. Our recovery of material was nearly one hundred percent of what was contained in the removed matrix, excepting the small isolated teeth of shrews. Six weeks were spent at Locality No. 3 removing approximately three cubic yards of dirt.

The following summer, 1938, we returned to Locality No. 3 and proceeded as in the summer before. Soon after beginning our work we discovered a few bone fragments in the clay deposit at Locality No. 2. We worked for one week devising a method of recovering the small fossils from the clay since it was impossible to dig them out.

Clods of dry clay were taken to a stream and placed in the water, where they rapidly disintegrated and the small bones dropped free from the clay particles. At once we began working on a washing device and soon had one perfected which would handle one-half shovel of dry clay. Four of these devices were made. Clay was removed from the deposits and hauled to the stream, where it was put through the washers and the remains placed on towels to dry in the sun. The recovery of specimens from clay is slower than that from the fine sand or sandy silt due to the time required for washing and drying. The fossils taken from the clay are badly broken, due to the cracks in the clay, which produced a large amount of useless fragmentary material. By this method of recovery, from one to five lower jaws were taken in a day with perfect drying conditions. It is impossible to wash specimens from wet or damp clay. Neither the sifting of quarried material nor the washing of fossils from the matrix are new field methods, but have been used by Brown (1908, p. 162) and Loomis (1926, p. 7).

The summer of 1939 also was spent working Locality No. 2 and Locality No. 3. The material recovered from Localities Nos. 1, 2, and 3 forms the basis of this paper. The fragmentary material indicates the presence of large forms though only a few bones and teeth have been found while removing the small amount of matrix. It has been deemed unwise to destroy the small material in an effort to recover larger forms. As soon as a nearly complete small fauna has been recovered with a good representative collection of individuals, the old method of "gutting" the locality will be used in an attempt to recover the remains of the larger forms.

GEOLOGY OF THE UPPER PLIOCENE BEDS

The geology of this area is being studied by Dr. H. T. U. Smith (1940) and by Dr. John C. Frye (1940 and MS). All references to any phase of the geology of the area are from papers in press, manuscripts, or from oral communication with the authors.

So far as is known, from our field work in Meade county, the exposed Upper Pliocene deposits occur as isolated patches to the west of Crooked creek in an area two miles wide and twelve miles long, where they crop out along the stream beds of east-flowing tributaries of Crooked creek. They are exposed only where the present streams have cut through the overlying Pleistocene deposits, leaving them exposed in the stream bed or where the streams by lateral planation have produced steep cut banks. The beds dip from the high plains on the west toward the present valley of Crooked creek,

at approximately 36 feet per mile, and are on the downthrow side of the most important of several faults, according to Frye (MS).

In most places where the Upper Pliocene deposits underlie the surface they are quite nonresistant to erosion, and produce a topography which slopes gently toward the southeast. Generally the lower slopes of the tributary valleys on the west side of Crooked creek are covered by grass and yucca or sage brush, hiding most of the deposit. The shallow overlying Pleistocene and Recent sediment hides the Upper Pliocene deposits where they pass under the high plains to the west. The exposed Upper Pliocene deposits studied consist of sand, sandy silt, clay and bog material. Some of the beds of sand are cemented with calcium carbonate. Below is given one of the more complete sections of the Upper Pliocene exposed in Meade county. This section was measured by Frye and Hibbard, in the "Deer Park" in Meade County State Park, fourteen miles south-southwest of Meade, Kansas.

	<i>Feet</i>
1. Surface soil	0.2
2. "Mortar" bed—cemented conglomerate, containing granite and caliche pebbles, and pebbles and cobbles of clay resembling the underlying beds, cross bedded. A few beds show a black stain of manganese. (Pleistocene.).....	10.0
3. Erosional unconformity	—
4. Sand, fine, and silt, gray and tan, mottled and streaked; loosely cemented. Thin bedded, but bedding does not weather out. (Top of Upper Pliocene beds.).....	2.0
5. Clay and silt, gray and tan, brown at top. Tough when dry. (Rexroad fauna.)....	3.4
6. Sand with some silt and clay, light pink-tan, massive, fairly loose, contains a small amount of caliche.....	5.4
7. Clay, silt and sand, red-brown and gray, with caliche nodules. Becomes more calcareous upward	2.0
8. Sand with some gravel, tan, loose, with a few cemented beds, partly covered.....	17.8
	40.8

The fauna discussed in this paper was taken from clay, sandy silt, fine sand included in lenses in the silt, and from bog material, at the three isolated exposures previously mentioned. No fossils have been recovered in place from the thick cross-bedded channel sands. The fossils coming from the bog material are poorly preserved, and to date only teeth have been recovered from it in good condition. Bones in the bog material are represented only by a fine reddish-brown powder. The bones taken from the clay are stained a reddish-brown and are more fragile than those taken from the sandy silt and the lenses of fine sand in the silt. The specimens taken from the lenses of fine sand within the sandy silt, and from the sandy silt itself are nearly white in appearance, and are very soft when moist, but become hard when dry.



TEXT FIG. 1. Outline map of western United States showing location of the principal Upper Pliocene vertebrate localities.

AGE AND RELATIONSHIPS OF THE REXROAD FAUNA

Continental deposits of the Upper Pliocene are poorly known in North America. A number of scattered localities have yielded fragmentary fossils indicating an Upper Pliocene age, though only three deposits have yielded large enough mammalian faunas to be useful in a careful study of comparative ages within the Upper Pliocene. The first discovered deposit of Upper Pliocene age in North America was that of the Blanco beds in Crosby county, Texas, which was reported by Cummins (1890). In his report Cummins gave two sections measured near Mount Blanco, Texas. He named the beds the "Blanco Canyon Beds" and did not attempt to determine their exact geological age because of insufficient data. Cummins collected some vertebrates from his horizon No. 5 (Packsand) which were sent

to Cope for identification. Cope (1892) published on the fragmentary remains. Because of the interesting fauna he then accompanied Cummins in the field to make a better collection of vertebrates. Cope (1893) then published an account of the entire vertebrate fauna. It was, however, not until Gidley (1903) published his report on the work at Mount Blanco that the distribution and position of the Blanco beds in Cummins' sections were clearly understood. Gidley pointed out that Cummins' two sections, measured near Mount Blanco, contained both Blanco beds and older Tertiary material. Gidley restricted the name "Blanco beds" to those of Upper Pliocene age only and from his work in the area drew the following conclusions: (1) "The fossil-bearing formations are fluvial, not lacustrine in origin," (2) "The Blanco has a limited distribution."

Following is a list of fossil mammals known from the Blanco fauna:

Edentata:

- Megalonyx leptostomus* Cope.
- Glyptotherium texanum* Osborn.

Carnivora:

- Borophagus diversidens* Cope.
- Osteoborus hillanus* (Cope).
- Canimartes cumminsii* Cope.

Proboscidea:

- Serbelodon* (?) *praecursor* (Cope).
- Rhynchotherium falconeri* Osborn.
- Stegomastodon successor* (Cope).
- Stegomastodon texanus* Osborn.

Perissodactyla:

- Plesippus simplicidens* (Cope).
- Plesippus cumminsii* (Cope).
- Nannippus phlegon* (Hay).

Artiodactyla:

- Platygomus bicalcaratus* Cope.
- Platygomus texanus* Gidley.
- Pliauchenia spatula* Cope.

Johnston (1937, 1938) and Stirton and Christian (1940) have made preliminary reports on the Cita Canyon fauna of Randall county, Texas. Johnston (1938) calls attention to "an assemblage of animals related to the Mount Blanco fauna on the one hand and the Lower Pleistocene of Rock creek on the other." The fauna is Upper Pliocene in age and its exact relationship to the Blanco fauna awaits the publication of Johnston's manuscript, which has been greatly delayed because of his untimely death. The Cita Canyon fauna is considerably larger than the Blanco and will help greatly in giving a clearer picture of the Upper Pliocene faunas of the high plains region.

The second Upper Pliocene fauna to be reported was the Pittsburg of California by Merriam (1903). Since that time a number of localities in California have yielded a few specimens of Upper Plio-

cene age, such as the Tehama, San Timoteo, and Coso Mountains faunas.

Following is a composite list of Upper Pliocene mammalian faunas from California:

Edentata:	Proboscidea:
<i>Megalonyx</i> (?) sp.	<i>Pliomastodon</i> (?) <i>cosoensis</i> Schultz.
Carnivora:	<i>Stegomastodon</i> cf. <i>arizonae</i> Gidley.
<i>Borophagus pachyodon</i> (Merriam).	Perissodactyla:
<i>Borophagus solus</i> (Stock).	<i>Plesippus proversus</i> (Merriam).
<i>Canis</i> sp.	<i>Plesippus francescana</i> (Frick).
Rodentia:	Artiodactyla:
<i>Cosomys primus</i> Wilson.	<i>Platygonus</i> sp.
Lagomorpha:	Camelid sp.
<i>Hypolagus</i> cf. <i>limnetus</i> Gazin.	<i>Antilocapra</i> ? sp.
	<i>Odocoileus</i> ? sp.

Gidley (1922) described a rodent fauna from the Upper Pliocene of Arizona which is known as the Benson fauna. This is one of the best known small vertebrate faunas of the Upper Pliocene of North America. A few years later, Gidley (1930) published upon another Upper Pliocene fauna from Idaho, known as the Hagerman fauna. At present this is the most completely known mammalian fauna from the Upper Pliocene of North America.

Following is a list of the fossil mammals known from the Hagerman fauna:*

Edentata:	Lagomorpha:
<i>Megalonyx leptonyx</i> ? (Marsh).	<i>Hypolagus</i> near <i>vetus</i> (Kellogg).
Insectivora:	<i>Hypolagus limnetus</i> Gazin.
<i>Blarina</i> <i>gidleyi</i> Gazin.	<i>Alilepus</i> ? <i>vagus</i> Gazin.
Carnivora:	Proboscidea:
Canid sp.	Mastodont.
<i>Hyaenognathus</i> or <i>Borophagus</i> sp.	Perissodactyla:
<i>Canimartes</i> ? <i>idahoensis</i> (Gazin).	<i>Plesippus shoshonensis</i> Gidley.
<i>Canimartes</i> ? <i>cookii</i> (Gazin).	Artiodactyla:
<i>Lutra</i> (<i>Satherium</i>) <i>priscinaria</i> Leidy.	<i>Platygonus pearcei</i> Gazin.
<i>Felis lacustris</i> Gazin.	Camelid, cf. <i>Camelops arenarum</i>
<i>Machairodus</i> ? <i>hesperus</i> Gazin.	Hay.
Rodentia:	Camelid, cf. <i>Procamelus</i> or
Citellid sp.	<i>Tanupolama</i> .
Marmot sp.	Cervid sp.
<i>Castor accessor</i> ? Hay.	<i>Ceratomeryx prenticei</i> Gazin
<i>Thomomys gidleyi</i> Wilson.	
<i>Cosomys primus</i> Wilson.	
<i>Pliopotamus idahoensis minor</i>	
(Wilson).	

* *The Hagerman faunal list is essentially that given by Gazin (1936) with slight changes in nomenclature.

Following is a list of the fossil mammals known from the Benson fauna:

Carnivora:

Canid sp.

Mustelid sp.

Rodentia:

Citellus bensoni Gidley.*Geomys minor* Gidley.*Cratogeomys bensoni* Gidley.*Cupidinimus magnus* (Kellogg).*Dipodomys minor* Gidley.*Onychomys bensoni* Gidley.*Baiomys minimus* (Gidley).*Eligmodontia? arizonae* Gidley.*Sigmodon medius* Gidley.*Neotoma fossilis* Gidley.

Lagomorpha:

Hypolagus small sp.*Hypolagus? large* sp.

Proboscidea:

Cordillerion bensonensis Gidley.

Perissodactyla:

*Pliohippus? sp.**Nannippus phlegon* (Hay).

Artiodactyla:

Platygonus sp.*Procamelus? sp.**Pliauchenia? sp.**Merycodus? sp.*

The determination of the age of the Rexroad fauna as Upper Pliocene was based by Hibbard (1938) on the presence of *Equus* cf. *simplicidens* Cope, *Equus* cf. *cumminsi* Cope and *Nannippus phlegon* (Hay), as identified by Dr. R. A. Stirton, the absence of rhinoceros remains, which are abundant in the Middle Pliocene of Kansas, increase in the abundance of fragmentary remains of the early mastodonts, and total absence of true Pleistocene forms, e. g., *Paramyiodon*, *Smilodon*, *Castoroides*, *Lepus*, *Sylvilagus*, *Equus excelsus* and *E. niobrarensis*, mammoths, and bison.

Following is a list of the fossil mammals known from the Rexroad fauna:

Insectivora:

Sorex taylori Hibbard.*Blarina? sp.**Hesperoscalops rexroadi* Hibbard.*Scalopus* sp.

Chiroptera:

genus?

Carnivora:

Canis lepophagus Johnston.*Canis large* sp.*Procyon rexroadensis* Hibbard.*Brachyprotoma breviramis* Hibbard.*Spilogale rexroadi* Hibbard.*Taxidea taxus* (Schreber).*Trigonictis kansasensis* Hibbard.*Machairodus* sp.*Felis large* sp.*Felis lacustris* Gazin.

Rodentia:

Citellus howelli Hibbard.*Citellus rexroadensis* Hibbard.*Eutamias* or *Tamias* sp.*Geomys* sp.*Liomys centralis* Hibbard.*Perognathus gidleyi* Hibbard.*Procastoroides lanei* (Hibbard).*Onychomys* sp.*Baiomys rexroadi* Hibbard.*Peromyscus kansasensis* Hibbard.*Eligmodontia? arizonae* Gidley.*Symmetrodontomys simplicidens*
Hibbard.*Sigmodon intermedius* Hibbard.*Parahodomys quadriplacatus*
Hibbard.

<i>Pliotlemmus antiquus</i> Hibbard.	Perissodactyla:
<i>Phenacomys primaevus</i> Hibbard.	<i>Plesippus simplicidens</i> (Cope).
<i>Ogmodontomys poaphagus</i> Hibbard.	<i>Nannippus phlegon</i> (Hay).
<i>Pliopotamys meadensis</i> Hibbard.	Artiodactyla:
Lagomorpha:	<i>Platygonus</i> sp.
<i>Pratilepus kansasensis</i> Hibbard.	Camelid small sp.
<i>Dicea lepuscula</i> Hibbard.	Camelid large sp.
<i>Nekrolagus progressus</i> (Hibbard).	Cervid sp.
<i>Hypolagus regalis</i> Hibbard.	<i>Capromeryx?</i> sp.
Proboscidea:	
Mastodont sp.	

Correlation of the fauna. The absence of edentates from the Rexroad fauna cannot be taken as evidence that they did not make up a part of that fauna. Their apparent absence is probably due to inadequate collecting of the larger forms.

The insectivores of the Rexroad fauna provide no correlation with the other Upper Pliocene faunas because of the scarcity of insectivores in other collections. *Scalopus* has been reported from the earlier Pliocene of Nebraska by Matthew (1924) and is known from the Pleistocene and Recent.

A number of carnivores are known from the Blanco, Hagerman and Rexroad faunas, but only a few forms are sufficiently well known to be used in correlation. Carnivores, as a rule, enjoyed a wide geographical distribution, and not until the vertical range of a species is known can it be depended upon for an accurate horizontal correlation; therefore, generalizations can be made only from the knowledge of other fossil and recent forms. *Canis lepophagus* occurs both in the Cita Canyon and the Rexroad faunas. *Felis lacustris* occurs both in the Hagerman and the Rexroad faunas. We may safely assume that both of these forms ranged as widely during the Upper Pliocene as *Canis latrans* and *Felis concolor* do today. On the basis of these two fossil forms the three faunas appear to be of approximately the same age, if we disregard the vertical range of the fossil species, which is not known at present. From our knowledge of the remaining carnivores there is at present nothing in common between the Upper Pliocene faunas unless *Trigonictis* from the Rexroad fauna and *Canimartes?* from the Hagerman fauna are generically the same. A clear understanding of the taxonomic position of these two forms depends upon more adequate material. It is interesting to note that *Brachyprotoma*, an extinct Pleistocene genus, occurs in the Rexroad, and *Spilogale* is represented by a distinct species. From a study of the material at hand, it appears that

the *Taxidea* show no change from Upper Pliocene to the present time.

The rodents, as a whole, show a greater plasticity than the other groups of mammals, and, therefore, may be considered as better indicators of environmental conditions. Compared with carnivores, the geographical range of a given rodent species is more limited, and consequently we may expect a greater difference between faunas separated by differences in latitude and altitude and especially when separated by both latitude and altitude. A rodent fauna has never been collected from the Blanco or Cita Canyon beds of Texas, but rodents are present in these deposits and especially in the Cita Canyon, where a number of fragmentary bones were observed in the summer of 1939. The collecting methods in these deposits should be revised if small material is to be recovered. If the Blanco and Cita Canyon beds are the same age as the Benson, a rodent fauna from them should be more nearly identical with the Benson than with that of any of the other well-known Upper Pliocene faunas because of the close geographical relation of the three deposits and only a slight difference in altitude. The Rexroad fauna, if the same age as the other Upper Pliocene faunas, should show a closer relationship with the Cita Canyon and Blanco faunas than with the Benson fauna, but a closer relationship with the Benson than with the Hagerman fauna. These suppositions are based upon the geographical relation of the faunas.

Citellus is known from most of the Upper Pliocene faunas. The differences between the Benson and Rexroad forms are no greater than the differences between the present citellids of the respective regions.

Geomys occurred in both the Rexroad and Benson faunas, and occurs in the present fauna of western Kansas. *Thomomys* is known from the Hagerman and *Cratogeomys* from the Benson. To date *Cratogeomys* is not known to occur in Kansas earlier than the Recent.

The heteromyids are best known from the Benson, and at present furnish no evidence for correlation between faunas, due to the absence of sufficient material from the other faunas.

The following genera of the cricetid rodents are common to the Benson and Rexroad: *Onychomys*, *Baiomys*, *Eligmodontia*? and *Sigmodon*. The abundance of these forms is about the same in both faunas, *Sigmodon* being far more abundant than the other genera in both deposits. The species of *Eligmodontia*, reported by Gidley

from the Benson, does not belong to that genus as known today, though the specimen has many characters in common with the Central and South American genera *Akodon* and *Eligmodontia*, and with *Symmetrodontomys* from the Rexroad, which it closely resembles.

The genus *Eligmodontia*? or *Symmetrodontomys* could not have given rise to *Peromyscus* and shows no close relationship to it, nor to *Reithrodontomys*, *Onychomys* or *Oryzomys*. Regardless of the fact that Hibbard (1939b) referred (with question) a form from the Middle Pliocene of Kansas to the genus *Oryzomys*, the fossil evidence at hand today indicates that *Reithrodontomys* and *Oryzomys* made its appearance in Central North America about the same time as the subgenus *Peromyscus*; that is, approximately middle to late Pleistocene time.

Voles and lemmings are not known from the Benson fauna. This may be due in part to the geographical position of the deposit. They are well represented in the Rexroad, both by genera and individuals. In this respect, the fauna shows a close relationship to the Hagerman.

Because of the geographical position of the Rexroad fauna one would expect to find it an intermediate fauna between the Benson and Hagerman if they were all of the same age; this opinion is based upon knowledge of the recent mammals of these areas. The Hagerman fauna is considered to represent a northern fauna and the Benson fauna a southern fauna because of their geographical position. The Rexroad seems to include the more tolerant species from both the northern and southern areas. The presence of *Pliopotamys* indicates a close age relationship between the Hagerman and the Rexroad faunas.

Pliolemmus antiquus, *Phenacomys primaevus*, and *Pliopotamys meadensis* may be forms that appeared late in the Rexroad fauna, since they have never been recovered from Locality No. 3; nor from the clays of No. 2 that have produced a fauna identical with No. 3. The variation in *Procastoroides* was previously pointed out. I do not believe that more than one species of the beaver was established in the Rexroad fauna at any one time. The size variation of the teeth is greater than individual or age variation. Therefore, it may represent a changing beaver fauna; if so, it will not be clearly understood until more material is available. It is well to point out again the type of deposits at the three localities. Locality No. 1 is well covered by slump and reworked materials from the higher surrounding areas. The fossils taken from this quarry were largely

recovered by sifting the diggings of the CCC camp. At this locality, there is, resting unconformably upon the Upper Pliocene clay, Pleistocene sand and gravel, and reworked lime nodules from the higher outcrops of the Upper Pliocene. This rubble and top soil ranges from one foot to nearly three feet in depth. From the reworked lime nodules and fine sand were recovered a large number of reworked Upper Pliocene horse teeth, mastodont teeth, and camel teeth. The small rodent material showed no signs of being redeposited, though there is a possibility that some of it could have come from the reworked material as well as from the underlying clays, since it was sifted from the dumps. At Locality No. 2, a sand pocket was found in the clay. This pocket, though exposed at the surface, was completely surrounded by clay, which was in place, and not slumped into its present position. The pocket was approximately three feet in diameter and ten feet deep, leading directly into a bed of sand below the clay which is definitely a part of the Upper Pliocene. *Pliolemmus*, *Phenacomys* and *Pliopotamys* were recovered only from this sand pocket, and never from the clays at this quarry. This sand pocket produced horse teeth identical with those taken from the clay deposits at No. 2 and No. 3. The exposed bank of sandy clay at No. 2 is unconformably overlain by a Pleistocene gravel, and the material coming from the clay was definitely in place. The No. 3 exposure presents no possibility of a mixed fauna of younger age as it is a sheer cut with the Upper Pliocene deposit exposed at the base and overlain near the top by Pleistocene gravel. There is the possibility that these forms represented rare individuals within the fauna or forms just beginning to occur because of the extension of their ranges.

The rabbits have to date been of but little help in the determination of the age of the fauna. *Hypolagus* occurs in the Benson, Hagerman and Rexroad faunas; because of its range from Lower Pliocene to Pleistocene and its poorly known species it does not afford a basis for correlation. The other genera are distinct and have closer relationships with the earlier Pliocene rabbits than the Pleistocene forms.

Horses are well known from the Blanco, Hagerman, and Rexroad, and, in part, from the Benson. At present the great difficulty in using the horse for time correlation is that its vertical range is not known. On the basis of the presence of *Nannippus phlegon*, the Blanco, Benson and Rexroad seem to be more closely related to one another than they are to the Hagerman, unless *Nannippus* is a

southwestern form. On the basis of the horse material the age of the Rexroad, Blanco and Benson are the same.

The artiodactyles are not well enough known from the Rexroad to be used in correlation in age.

The Hagerman consists of what is considered as a northern fauna and the Benson a southern fauna. The Rexroad fauna possesses what is considered as both northern and southern elements. On the basis of the fossil evidence at hand, the Rexroad, Blanco, Benson, and the Hagerman faunas are of the same approximate age, if one considers all the mammals of the Rexroad fauna as contemporaneous. The difference between the faunas is accounted for apparently by the geographical positions of the faunas. However, if it should be proven in the future by additional material that *Pliopotamys*, *Pliolemmus* and *Phenacomys* represent a part of a younger fauna, this would indicate that the Hagerman fauna is probably slightly younger than the Rexroad fauna. The difference between the Blanco and Hagerman faunas was considered by Gazin (1936) as probably being only of geographic significance. The present elevations of the areas from which the faunas were taken are not noticeably different from one another, ranging approximately from 2,500 to 3,600 feet. The Benson fauna is situated at approximately latitude 31° 30' N., Blanco approximately 33° 30' N., Rexroad approximately 37° N., and the Hagerman 42° 30' N.

Because of the uncertainty of the correlations of faunas in North America, it seems unwise at the present to attempt a correlation with European or Asiatic faunas. Much has been written on the subject, but no forms that were found in the Rexroad fauna will afford any better material for correlation than those previously known. Pilgrim (1940) in one of the latest papers on correlation brings out a number of points for consideration in correlation. One of the best is his statement, "It cannot, however, be denied that the nearer we approach to recent times, the slower is the rate of change." This has been observed by most students of the vertebrates in all of the classes except the mammals and when more thought is given to this and to the fact that the occurrence of like forms in widely separated areas cannot be considered as an indication of synchronous time, more accurate correlations will be attempted.

PALEOECOLOGY OF THE REXROAD FAUNA

Paleoecology is a division of paleontology that has remained nearly untouched. This is due in part to the lack of many essential data, and in part to the fact that anyone attempting to reconstruct past conditions upon scanty evidence hesitates because of the danger of the misinterpretation of the material if it does not come from a trapped deposit such as a cave, tar pit, etc. Studies of the floras, the invertebrate and vertebrate faunas, stratigraphy, physiography, palaeogeography, and the climatology have rarely been made for any given deposit. Paleontologists have seldom been able to find floras and faunas sufficiently well associated in a given deposit to furnish a sound basis for the description of the environment at the time the deposit was laid down.

The best guide for anyone attempting to work in the field of vertebrate paleoecology is given by Case (1919) in "The Environment of Vertebrate Life in the Late Paleozoic in North America; a Paleogeographic Study," which resulted from a number of years of work in the field of paleontology. Further help in attacking a study of paleoecology is Barrell's (1908) paper on, "Relations between Climate and Terrestrial Deposits," and the two reports of the Committee on Paleocology (Twenhofel, chairman, 1936 and 1937). Clements (1918) discussed the "Scope and Significance of Paleocology," based on paleobotany, in which he points out many factors to be observed in such a study. Chaney has contributed more to paleoecology of floras of the Tertiary than any other worker in North America. His papers are very useful in the study of climatic conditions in the Tertiary, and provide a starting point in a study of certain mammalian faunas of that age.

In attempting a discussion of the paleoecology of the Rexroad mammalian fauna, we must assume that climate controls the development of the vegetation and that climate and vegetation control directly or indirectly the animal life. Also the following facts must be considered; first, that known fossil faunas usually consist of only a few individuals of a given species. Therefore, it is not always possible to distinguish between rare and common species in a fauna. Second, there is always the possibility of redeposition of slightly older forms with a recent fauna, or vice versa, and the forms found together in stream deposits may represent a mixture of all that occurred in every part of the drainage system of the stream. One cannot assume that the fossils taken from a stream deposit belong to a

local fauna. The larger the stream that laid down the deposit, the greater the chance that some of the fossils are from widely separated areas.

From a study of the few exposed deposits, it seems that the Meade area in Upper Pliocene time presented a rolling surface with a wide river valley bordered by low rolling hills covered with vegetation. The low gradient stream is considered to have been mountain-fed and to have flowed in a southward direction toward the Gulf of Mexico. The climatic conditions must be reconstructed from the characters of the fauna.

A knowledge of the fossil flora of this area would help one to interpret both the climate and the fauna, but this information is entirely lacking because no plant remains could be identified.

Associated with the mammals of the Rexroad fauna were the following mollusks which were identified by Dr. F. C. Baker.

Fresh-water shells:

<i>Pisidium</i> sp.	<i>Helicodiscus singleyanus</i> Pilsbry.
<i>Stagnicola reflexa</i> (Say).	<i>Gastrocopta tappaniana</i> C. B. Adams.
<i>Physa anatina</i> Lea.	<i>Gastrocopta holzingeri</i> (Sterki).
<i>Ferrissia rivularis</i> (Say).	<i>Gastrocopta cristata</i> Pilsbry and Vanatta.
<i>Ferrissia parallela</i> (Haldeman).	<i>Vertigo hibbardii</i> F. C. Baker.
<i>Menetus kansasensis</i> F. C. Baker.	<i>Vertigo milium</i> Gould.

Land snails:

<i>Carychium pereziquum</i> F. C. Baker.	<i>Pupoides marginatus</i> (Say).
<i>Polygyra mooreana tholus</i> (Binney).	<i>Pupoides inornatus</i> Vanatta.
<i>Retinella electrina</i> (Gould).	<i>Strobilops sparsicostata</i> F. C. Baker.
<i>Retinella rhoadsi</i> Pilsbry.	<i>Vallonia gracilicosta</i> Reinhardt.
<i>Retinella wheatleyi</i> Bland.	<i>Succinea grosvenori</i> Lea.
<i>Hawaii miniscula</i> Binney.	<i>Succinea grosvenori gelida</i> F. C. Baker.

Doctor Baker wrote in a letter dated January 29, 1940, "The ecology of this deposit appears to have been a river or slough, judged by the character of the fresh-water fauna. The land species lived in well-wooded situations and were probably washed into the fresh-water bodies during rains, from the hillsides. The great abundance of species indicates that at this time the mollusk fauna was well developed. I would say the climate was warm."

The remains of fishes are chiefly spines of catfish, which will be studied in the near future. Apparently the presence of catfish would indicate a stream with more or less permanent pools of water having partially silted bottoms or oxbow lakes along the stream valley.

The amphibian fauna has not been identified, though Doctor Taylor says, "It consists of the remains of salamanders, frogs and toads,

representing an amphibian fauna larger than the present amphibian fauna of Meade county, with a decided increase in the number of species of frogs." This would indicate a more humid condition than exists at the present time in the area.

The fragmentary reptile material indicates a lizard and snake fauna comparable in number with the present-day fauna, but at present this material does not throw any light on past ecological conditions.

The fossil bird material has not been identified, therefore it is impossible as yet to use the material in an ecological study.

The mammalian fauna is represented by 8 orders, 37 identified genera and 32 identified species. This is a larger mammalian fauna than is known to have occurred in the area in Recent time, provided the fossil forms represent an associated fauna that lived together in that area during the Upper Pliocene and not an assemblage of forms some of which represent in part faunas of a different age or forms washed in from areas far upstream. The small forms show no signs of having been reworked or having been carried a great distance before deposition, though to date no complete skeletons have been found associated. This indicates that they neither died nor were they trapped in the place where they were deposited. The isolated horse teeth indicate stream transportation, though they are not polished. This would suggest that they had been moved but a short distance, since gravel and coarse sand are absent in association with the material. It must be kept in mind that carcasses of dead animals may be washed miles along a stream course, because of their bouyance, and deposited in areas in which they did not live without the bones showing evidence of stream transportation. In the following discussion the assemblage of fossil mammals is treated as having existed as a contemporaneous fauna in the area in which they were collected. It must be kept in mind that this is not a proven fact and certain evidence is to the contrary. Many of the questions arising from this study will require years of careful work for their answer.

The following groupings of the fossil mammals are based upon the adaptive characters presented by them and upon the known habitats of living species of genera represented in the fauna. They are grouped as far as possible under the following communities: upland grass community, semiaquatic community, meadow and marsh community, forest community, and valley slope community. The term community as here employed refers to an assemblage of mam-

mals living under the same, or at least similar, conditions of environment.

Upland grass community: It is assumed that well-developed grassland existed on the upland in this region during the Upper Pliocene because of the abundance of the remains of the horses (*Equus* and *Nannippus*) which are adapted for a grazing habitat. A grassy upland would also furnish a suitable habitat for the camels and the antelope. Smaller mammals of the Rexroad fauna that might also have occurred in the upland association are *Citellus*, *Onychomys*, and *Perognathus*. These genera live in the region at the present time and they also live westward in more arid regions and eastward in a more humid region. It is reasonable to assume that at least one of the Upper Pliocene rabbits inhabited the upland, though there is not enough known of the skeleton of these forms to indicate which were adapted for life on the plains. The badger (*Taxidea taxus*) would undoubtedly be found in the grassland.

Semiaquatic community: The type of deposition of the Upper Pliocene material indicates that there existed a larger stream at that time than the present Crooked creek, in fact a stream comparable to the Cimarron river before the 1914 flood. The presence of the large beaver (*Procastoroides*) in the Upper Pliocene deposit also points to a permanent water supply along the major stream. There is no proof that *Procastoroides* constructed dams as does our present *Castor*. The assumption may be made, however, that if these beavers did not construct dams, they must have lived around permanent bodies of water large enough to furnish a suitable food supply. We cannot believe that the large incisors of *Procastoroides* were adapted for feeding upon grass and aquatic vegetation, and it seems probable, therefore, that the foliage and bark of trees made up a considerable part of the diet of the animal. It seems reasonable to assume that this form constructed dams, even though no evidence of a dam has been found in the deposit. If the beavers constructed dams these must have played an important part in maintaining a slow run-off of surface water and also have helped to maintain a more nearly constant water table in the lowlands throughout the year. In the case that dams were constructed the ponds behind them would provide habitats suited to other vertebrates, such as fishes, amphibians, and birds. The ponds would pass through certain stages in succession, leading to the production of a beaver meadow. A region such as this would support an abundance of plant and animal life.

It should be pointed out at this time that the form *Pliopotamys* which is known from two rami collected by the sifting of the CCC dumps at Localities Nos. 1 and 2, may be a part of a younger fauna, and was considered as an *Ondatra* by Wilson (1933) in the Hagerman fauna. The form may have been semiaquatic in habit though it is not a muskrat. There is no evidence to date as to whether this vole inhabited the stream banks or the meadows and borders of the marshes.

The raccoon would be expected to frequent the edges of the streams and marshes, as it does today.

Meadow and marsh community: The abundance of rami (16) of *Sorex taylori* recovered in good condition from the stream deposit indicates that it was not a desert form, but one that lived along the streams and marshes, apparently in habitats similar to those in which the majority of *Sorex* live at present. *Sorex* is not known to occur in Kansas at the present time. The closest points of known occurrence are northwestern Nebraska and the edge of the Rocky Mountains in eastern Colorado. *Sorex taylori* appears to have been a form living in the meadows and along the marshes and stream banks. If so, it seems to indicate that a lower summer temperature and a slightly more humid condition existed in the region where it lived in the Upper Pliocene than exists there at present. The abundance of genera and individuals of microtine rodents indicate that meadows and marshes existed commonly in the Upper Pliocene valleys. The voles and lemmings are herbivores possessing hypsodont teeth which are adapted for masticating the tender shoots of grasses. Voles, with the exception of the muskrat, are not known to occur in the area at the present time and their abundance in the Rexroad fauna indicates conditions which provided grassy habitats along the valleys. *Ogmodontomys*, a vole the size of a large *Microtus*, is second in abundance of mammals recovered from the deposit. It should be pointed out again at this time that *Pliolemmus*, a lemming, and *Phenacomys* may represent a part of a younger fauna, since they were recovered from the siftings of the CCC dumps at Localities Nos. 1 and 2. At present these forms are found only in boreal faunas. The cotton rat (*Sigmodon*) ranks third in the number of Upper Pliocene individuals collected and also indicates the existence of meadows. *Sigmodon* occurs at the present time in Meade county, where it is confined to the meadows bordering permanent streams and to the edges of marshes bordering the permanent springs. *Baiomys* would be expected to inhabit meadows

and the edges of marshes, if its habits in the Upper Pliocene were the same as those of the species found today on the coastal plains of Texas. The range of living *Baiomys* extends southward through Mexico, from the humid coastal plains well into the high arid plains. It is a genus that apparently possessed a wider range in central and southwestern United States before the Pleistocene than it does at present. *Geomys* may be considered to have inhabited the flood plains, drier regions of the meadows, and the valley slopes where the soil was suitable for burrowing. The moles probably lived in areas of the valleys possessing loose moist soil. Clays, dry packed soil and rocky soil act as barriers to this animal. Moles are common at the present time along the permanent streams of Meade county, especially around cottonwoods where the soil is shaded and remains more or less moist. The habits of the extinct rabbits are unknown. On the basis of material collected, *Pratilepus* is the most common rabbit in the deposit. It is three times as abundant as the other leporids. Because of its abundance it may have been a form that inhabited the meadows near the stream.

Forest community: The presence of mastodonts and deer, which were browsers, would indicate the presence of smaller or larger wooded portions along the stream. This indication supports the evidence furnished by the presence of the beaver. Also, these browsers may have ranged upon the slopes which in suitable areas probably supported trees or shrubs. The wood rat (*Parahodomys*), which is the most abundant form found in the Rexroad fauna, may possibly have inhabited the wooded areas. It may also have lived along the rock ledges, or among the rocks and shrubs on the slopes. This conclusion is based upon the present habitats of the related genera, *Neotoma* and *Hodomys*. *Parahodomys* was present in the Pleistocene Cumberland Cave fauna of Maryland, which points to an ability to live in a more or less wooded region. *Spilogale* would probably be found living in the rock ledges, under rocks along the slopes and in wood rat nests, as it does now in the region.

Valley Slope Community: The valley slope community can only be reconstructed from our knowledge of the existing valley slopes. There would be expected to be two types of slopes along the valleys in the Upper Pliocene as at present. Long, gradual slopes would have extended from the rim of the upland to the valley floor. These slopes would likely be covered with grass. This sort of slope would be used by the grazing forms of the upland as a route in coming down into the valley for water. The steeper slopes would probably be

in part rocky. Some of them also might be covered by scattered shrubs or by shrubs and trees, which would likely provide a habitat for the browsers such as the deer and mastodonts. *Parahodomys* and *Spilogale* might have lived here as has already been pointed out.

It is impossible to suggest the ecological relationships for some of the fossil mammals, since they are known only by extinct forms, of which the habits are unknown.

The extinct genera of ericetid rodents *Eligmodontia*? and *Symmetrodromys* have brachyodont teeth, which indicate an omnivorous diet and they may have ranged over several types of habitats. It is impossible to place the rabbits in any one community. Such forms as the carnivores probably ranged throughout most of the area, not being confined to any particular community.

It is possible, after having analyzed present ecological conditions, the data furnished by geological studies, and the evidence offered by a study of the Rexroad fauna of Meade county, to attempt to present a generalized picture of conditions which prevailed at the time the Rexroad fauna was living. Frye (MS) considers the region in southwestern Kansas when the Rexroad fauna was laid down as having been a rolling country, with an elevation approximately the same as at present, traversed by a low gradient stream which was mountain fed, flowing toward the south into the Gulf. The fauna gives evidence that there probably existed along the major stream valley areas of meadows, marshes and trees. It is logical to consider that portions of the steeper valley slopes were covered in part by shrubs and probably trees. These conditions exist in given areas of the county at the present time. The annual summer temperature for the area is indicated by the presence of the shrews and voles to have been somewhat lower than at present. The only vole known, living in the region at the present time is the muskrat, which is confined to the permanent streams. The fissure springs did not exist during the Upper Pliocene, as they come from the buried Upper Pliocene deposits (Frye, MS). The presence of the cotton rat in the Rexroad fauna indicates that the winters were probably no colder than at present, since Meade county is now on the northern limits of its present range. The cotton rat is found in Meade county at the present time, though confined to the grassy areas along the permanent bodies of water. The large number of species of frogs, the numerous land snails supposedly confined to wooded areas, and the presence of the shrew and voles in the Rexroad fauna seem to indicate that the summers were more humid at that time than in the region at the present

and that there were no extreme summer droughts. At least, the climate could not have been drier than at present. It does not seem possible that a permanently flowing stream alone would provide a more humid condition than that of the present in this region, because both Crooked creek and the Cimarron river were permanently flowing until a few years ago; therefore, a higher humidity would seem to indicate a greater rainfall in the Upper Pliocene than at present.

It therefore seems that the fauna as a whole indicates a climate more equable than at present, since the presence of *Sigmodon*, *Liomys*, *Parahodomys*, and *Baiomys*, all with southern affinities, indicates somewhat warmer winters; the shrew, voles, lemming and frogs indicate a more humid condition; while the beaver, mastodonts and deer indicate the greater abundance of trees and shrubs than at present. Furthermore, there is no evidence of the existence of great ice fields in the north, nor of cold ocean currents, at that time, which would make extreme winters much less likely than under present conditions.

The possibility must now be considered that the Rexroad fauna may be a mixture of two faunas, that is, *Pliopotamys*, *Pliolemmus* and *Phenacomys* may belong to a later fauna. In that case the remainder of the fauna would have largely southern and southwestern affinities. The living relatives of the following forms are confined to the southern United States, Mexico or Central America: *Procyon* (subgenus *Euprocyon*), *Spilogale rexroadi*, *Liomys*, *Perognathus*, *Onychomys*, *Baiomys*, *Peromyscus* (subgenus *Haplomylomys*), *Sigmodon*, *Parahodomys*, *Eligmodontia?* and *Symmetrodontomys*. If the fossils do belong to two distinct faunas the older or Rexroad proper would indicate clearly a warmer and more humid climatic condition than exists in that region at present.

On the other hand, if the Rexroad fauna is not mixed and represents a contemporaneous group of mammals then the presence of the lemming and *Phenacomys*, which are boreal forms, would indicate a cooler climate than the present or at least cooler summers. At the close of the Pliocene there was a slow shifting toward a cooler climate over the whole continent, with a chance for an invasion of forms from a more northern fauna.

SUMMARY

The Rexroad mammalian fauna from the Upper Pliocene of southwestern Kansas contains 8 orders consisting of 37 identified genera. Of these genera 10 were new. There are 32 identified species, of which 25 were new. The fauna was collected from a stream deposit consisting of sandy silt containing lenses of fine sand, from clay and from bog material.

On the basis of the fossil mammals the Rexroad, Blanco, Benson and Hagerman faunas are considered to be of approximately the same age. The differences between the faunas are considered to be only of geographical significance. The Rexroad fauna shows a closer relationship to the Blanco and Benson fauna than to the Hagerman fauna. While the fauna as a whole shows relationships with forms now found in Mexico and Central America rather than with the recent forms now found in southwestern Kansas, a few fossil forms possess boreal affinities.

From geological interpretation by Frye the fauna inhabited a rolling country approximately at the elevation of the region today. The region was traversed by a major stream of low gradient which was mountain fed and flowed southward toward the Gulf.

From the study of the Rexroad fauna there is evidence which indicates the existence of the following communities in southwestern Kansas at the time the fauna lived; upland grass community, semi-aquatic community, meadow and marsh community, forest community and valley slope community. The fauna indicates that meadow flats and timbered areas existed at least along portions of the Upper Pliocene stream valley, and that the climatic conditions then were not drier nor colder than at present. Moreover, there is some indication that climate in the Upper Pliocene was more equable than at present, without extremely cold winters or severely hot summers, and that there was a somewhat greater degree of humidity.

LITERATURE CITED

- BAKER, FRANK C. 1938. New land and fresh-water mollusca from the Upper Pliocene of Kansas and a new species of *Gyraulus* from early Pleistocene strata. *The Nautilus*, 51 (4):126-131.
- BARRELL, JOSEPH. 1908. Relations between climate and terrestrial deposits. *Jour. Geol.*, 16(2):159-190; 16(3):255-295; 16(4):363-384.
- BROWN, BARNUM. 1908. The Conard Fissure, a Pleistocene bone deposit in northern Arkansas: with descriptions of two new genera and twenty new species of mammals. *Mem. Amer. Mus. Nat. Hist.*, 9(4):157-208, pls. 14-25, figs. 1-3.
- CASE, E. C. 1919. The environment of vertebrate life in the late Paleozoic in North America: a paleogeographic study. *Carnegie Inst. Washington*, No. 283: 273 pp., 1 pl., 7 figs., 1 chart.
- CHANEY, RALPH W., and ELIAS, M. K. 1936. Late Tertiary floras from the High Plains. *Carnegie Inst. Washington*, No. 476:1-72, 10 figs., 7 pls.
- CLEMENTS, F. E. 1918. Scope and significance of paleoecology. *Bull. Geol. Soc. Amer.*, 29:369-374.
- COPE, E. D. 1892. A contribution to the vertebrate paleontology of Texas. *Proc. Amer. Philos. Soc.*, 30:123-125.
- 1893. The vertebrate fauna of the Blanco beds. 4th Ann. Rept. Geol. Surv. Texas, 4(1892):47-74, pls. 13-20, figs. 1, 2.
- CUMMINS, W. F. 1890. Report on the geology of northwestern Texas. *Texas Geol. Surv.*, 2d Ann. Rept.:359-435.
- FRYE, JOHN C. 1940. A preliminary report on the water supply of Meade artesian basin, Meade county, Kansas. *Bull. 35, State Geol. Surv. of Kansas*, 39 pp., 7 figs., 5 pls.
- GAZIN, C. LEWIS. 1936. A study of the fossil horse remains from the Upper Pliocene of Idaho. *Proc. U. S. Nat. Mus.*, 83(2985):281-320, pls. 23-33, figs. 21-24.
- GIDLEY, JAMES W. 1903. The fresh-water Tertiary of northwestern Texas. *Amer. Mus. Expeditions of 1899-1901. Bull. Amer. Mus. Nat. Hist.*, 19(26): 617-635, 7 pls., 4 figs.
- 1922. Preliminary report on fossil vertebrates of the San Pedro Valley, Arizona, with descriptions of new species of Rodentia and Lagomorpha. *U. S. Geol. Surv., Prof. Paper*, No. 131:119-131, pls. 34-35.
- 1930. A new Pliocene horse from Idaho. *Jour. Mamm.*, 11(3):300-303, pl. 18.
- HIBBARD, CLAUDE W. 1938. An Upper Pliocene fauna from Meade county, Kansas. *Trans. Kan. Acad. Sci.*, 40(1937):239-265, 5 pls., 2 figs.
- 1939. Notes on additional fauna of Edson Quarry of the Middle Pliocene of Kansas. *Trans. Kansas Acad. Sci.*, 42:457-462, 1 pl.
- 1941. New mammals from the Rexroad fauna, Upper Pliocene of Kansas. *Amer. Midland Nat.*, vol. 26, No. 2.
- JOHNSTON, C. STUART. 1937. Osteology of *Bismachelys canyonensis*, a new turtle from the Pliocene of Texas. *Jour. Geol.*, 45(4):439-447, 10 figs.
- 1938. Preliminary report on the vertebrate type locality of Cita Canyon, and the description of an ancestral coyote. *Amer. Jour. Sci.*, 35:383-390, 3 pls.
- LOOMIS, F. B. 1926. The evolution of the horse. *Marshall Jones Co.*, 233 pp., 25 pls., 41 figs.

- MERRIAM, C. HART. 1903. The Pliocene and Quaternary Canidae of the great valley of California. Univ. California Publ. Bull. Dept. Geol. Sci., 3:277-290, pls. 28-30.
- PILGRIM, GUY E. 1940. The application of the European time scale to the Upper Tertiary of North America. Geological Magazine, 77:1-27.
- SMITH, H. T. U. 1940. Geologic studies in southwestern Kansas. Kansas Geol. Surv. Bull., 34, 240 pp., 34 pls., 22 figs.
- STIRTON, R. A., and CHRISTIAN, WAYNE G. 1940. A member of the Hyaenidae from the Upper Pliocene of Texas. Jour. Mamm., 21(4): 445-448, 1 fig.
- TWENHOFEL, W. H. 1936. Report of the Committee on Paleoecology, 1935-1936. App. J., Ann. Rep. Div. Geol. and Geography, Nat. Research Council, 64 pp.
- 1937. Report of the Committee on Paleoecology, 1936-1937. Rep. Div. Geol. and Geography, Nat. Research Council, 63 pp.
- WILSON, ROBERT W. 1933. A rodent fauna from the later Cenozoic beds of southwestern Idaho. Carnegie Inst. Wash. Publ., 440:117-135, 2 pls., 8 figs.

